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Power Quality Improvement for Fluorescent Lighting

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ABSTRACT: Power factor is an important performance parameter of a system and improving power factor is very much essential for the economical and better performance of the system. If the power factor of a system for a given power requirement is poor, then large value of Volt – Amperes or the large amount of current required by the system which is drawn from the supply. Now it is seen that various measures are taken to improve the power factor of a given system. Power Factor Correction (PFC) mainly involves two techniques; Active PFC and Passive PFC. Passive power factor correction circuits have certain advantages, such as insensitivity to noise and surges, simplicity, reliability. On the other hand, also they have several drawbacks. Active PFC solutions are more suitable options for achieving near unity power factor and sinusoidal input current waveform with extremely low harmonic distortion. Various converter topologies used for power factor correction, such as buck, buck-boost and cuk etc.

KEYWORDS: Power Factor Correction, Zero voltage switching, CFL.

I.INTRODUCTION

Now a day's most of the industries, underground railways, underground parking spaces and multi storied buildings etc. are uses wide range of lighting systems. About 25% to 35% of total power generated across the world is consumed for the lighting purpose. Compact Fluorescent lamps (CFL) are becoming very simple and very popular as a source of artificial light. The ballast is used for the starting purpose for the fluorescent lamp. The ballast provides sufficient voltage to start the lamps and regulates the current to the lamps. If a fluorescent lamp connected directly to a high voltage power source would rapidly and uncontrollably increase its current draw due to absence of ballast. There are two types of ballasts electromagnetic and electronic ballast. Due to rapid development in the power electronics technologies, the high frequency electronic ballast is preferred over the electromagnetic ballast to drive the fluorescent lamp. The fluorescent lamp is a low pressure mercury discharge lamp in which light is produced by fluorescent material like phosphors which are energized by ultraviolet rays. The fluorescent lamp consists of a gas tube which is completely filled with argon gas and mercury vapours. Also it consists of two filament electrodes at each end. The inner part of the tube is coated with phosphors material and the cathode filament electrodes are coated with such materials which can assist in emission of more electrons. With a proper ignition voltage, an electric discharge is produced between both the electrodes. This discharge generates mostly the invisible ultraviolet radiation and phosphor absorbs these ultraviolet radiations to produce visible light.

II. BACKGROUND AND MOTIVATION

In recent years, there have been increasing demands for high power factor and low total harmonic distortion (THD) in the current drawn from the utility. With the stringent requirements of power quality, power-factor correction (PFC) has been an active research topic in power electronics, and significant efforts have been made on the developments of the PFC converters. Power supplies with active power factor correction (PFC) techniques are becoming necessary for many types of electronic equipment to meet harmonic regulations and standards, such as the IEC 61000-3-2. The quality of the currents absorbed from the utility line by electronic equipment is increasing due to several reasons.

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In fact, a low power factor reduces the power available from the utility grid, while a high harmonic distortion of the line current causes different problems like Electromagnetic Interference and cross interferences, through the line impedance, between different systems connected to the same grid. From this point of view, the standard rectifier employing a diode bridge followed by a filter capacitor gives unacceptable performances. Thus, many efforts are being done to develop interface systems which improve the power factor of standard electronic loads and the system. An ideal power factor corrector (PFC) should emulate a resistor on the supply side while maintaining a fairly regulated output voltage.

III. POWER FACTOR

Power Factor is the ratio of the power needed to do the work within customer premises to the power delivered by the utility. A power factor of 1.0 is ideal. Equipment located in customer premises emits reactive power that lowers the power factor. There are devices that can be attached to the loads to raise the power factor and reduce the amount of energy lost as heat on the wires in buildings and on the electrical distribution system [3].
Input power factor (PF) is defined as,

$$PF=\frac{\text{REAL POWER}}{\text{APPARENT POWER}}$$

PF is expressed as decimal number between zero and one (0 and 1).A non-corrected power supply with a typical PF equal to 0.65 will draw approximately 1.5 times greater input current than a PFC supply (PF = 0.99) for the same output loading. The non-corrected supply requires additional AC current to be generated which is not consumed by the load, creating I^2R losses in the power distribution network.

IV.PROPOSED PFC ELECTRONIC BALLAST

The electronic ballast is shown in figure 1, which consist of a PFC buck-boost converter and a high frequency series resonant inverter.

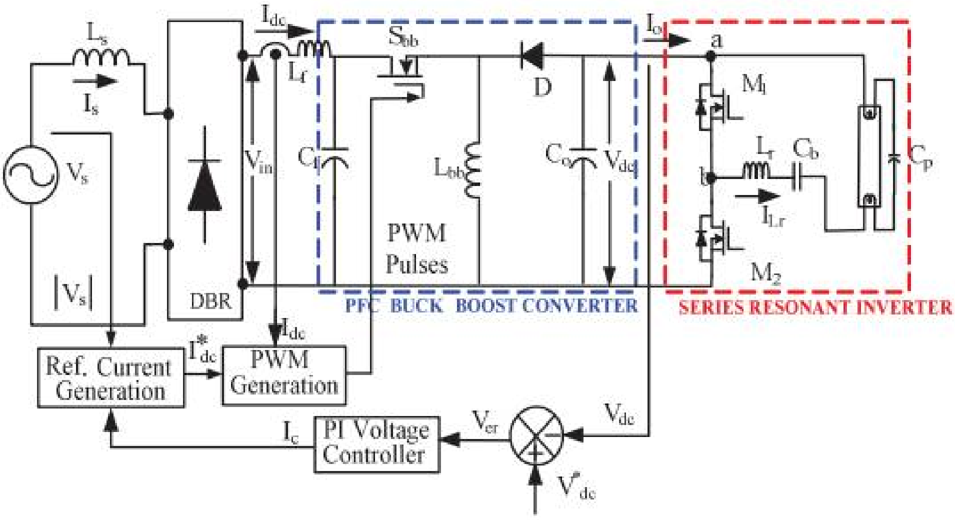

Fig:1:Buck-Boost converter based electronic ballast

The PFC converter improves input power factor and series resonant inverter provides sufficient ignition voltage and supplies constant lamp current at high frequency to drive the fluorescent lamp. The quasi-half bridge inverter provides a square wave voltage which is fed to the load through an LC network which filters the higher order harmonics present in the square wave. Since the harmonics of the square wave are attenuated by the LC network, an analysis is carried out using only the fundamental component of the square wave voltage. The solid state power switches M_1 and M_2 are alternately turned on and off at a switching frequency of 60 kHz. The switching frequency of the resonant inverter is kept more than the resonance frequency of the inverter to confirm the zero voltage switching (ZVS) which reduces switching losses at high frequency.

MODES OF OPERATIONS

The operating modes and the resonant inverter key waveform are shown below. It consists of 4 modes. The sinusoidal input voltage is considered as constant in each switching cycle, since the switching frequency is much higher than the line frequency.

Mode 1($t_0 < t < t_1$)

Figure 2 shows the mode –1 operation.

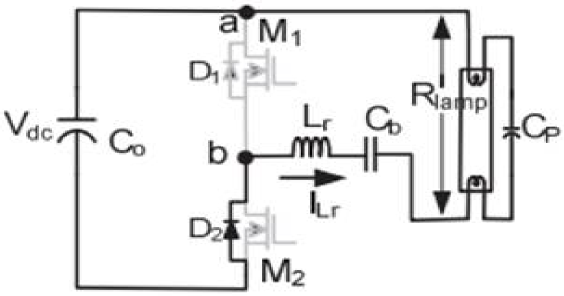

Fig:2: Mode 1

At t_0, body diode D_2 starts conducting and the dc link capacitor is charged and during this interval the gate pulse (S_2) is also applied to active switch M_2.

Mode 2($t_1 < t < t_2$)

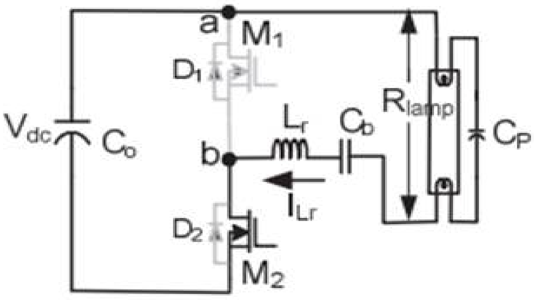

Fig:3: Mode 2

The above figure 2.24 shows the mode 2. At t_1 MOSFET M_2 is turned on at ZVS-capacitor discharged-direction of inductor current changes

Mode 3($t_2 < t < t_3$)

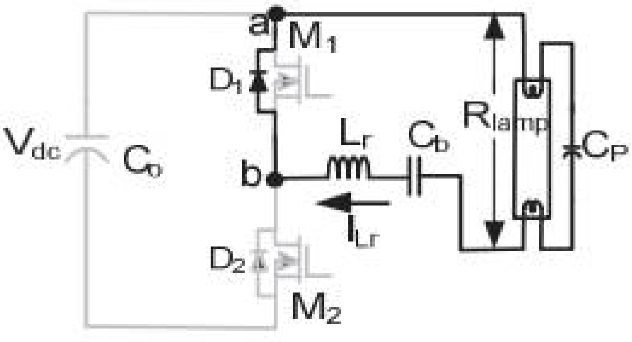

Fig:4: Mode 3

MOSFET M_2 is turned off at t_2 - diode D_1 starts conducting- current flow in the same direction due to resonant nature of the circuit. During this interval the gate pulse (S_1) is also applied to active switch M_1.
The path of the current is,
$D_1 \Rightarrow (R_{lamp}||C_p) \Rightarrow C_b L_r \Rightarrow D_1 \Rightarrow$

Mode 4($t_3 < t < t_4$)

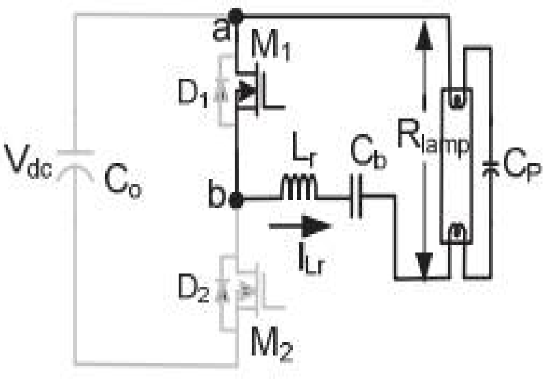

Fig:5: Mode 4

At t_3 the MOSFET M_1 starts conducting and it is evident that it is tuned on at ZVS. This ensures the change in the direction of the resonant current. The path of current is given. This mode ends up at t_4 and then mode-1 to mode -4 repeat for the next switching cycle.
$M_1 L_r C_b \Rightarrow \Rightarrow (R_{lamp}||C_p) \Rightarrow M_1 \Rightarrow$

It is shown from the different operating modes over a switching cycle of the above circuit that both MOSFETs (M_1 and M_2) are operating at zero voltage switching (ZVS). Moreover, to achieve zero voltage switching (ZVS) operation of both active power switches the necessary condition is that the inverter circuit must operate at lagging power factor.

V.MATLAB MODEL

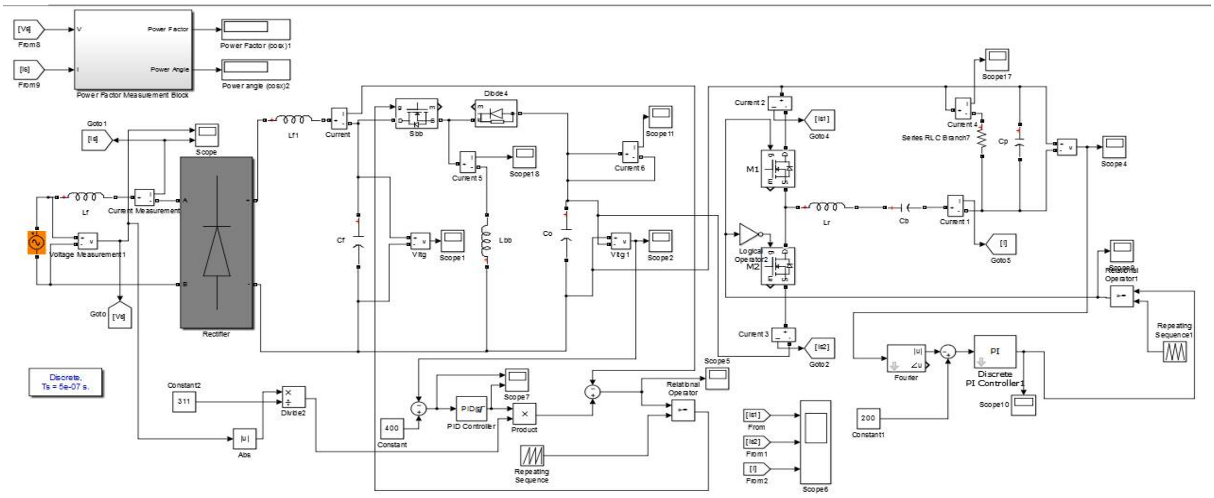

Fig:6:Matlab model of buck-boost based electronic ballast

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The figure 6 shows the power factor correction buck-boost converter based electronic ballast and it is modelled in MATLAB/Simulink tool, in this the fluorescent lamp is considered as a resistor.

Power factor measurement block

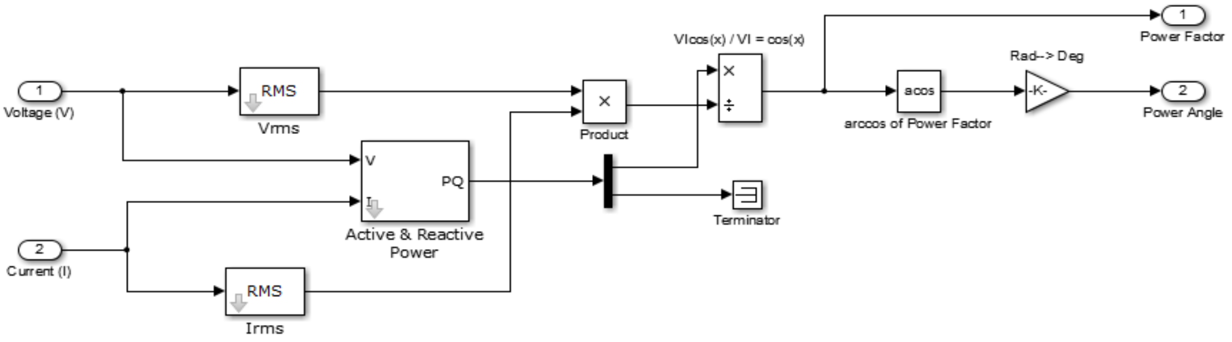

Fig.7: Power factor measurement block

Fig.7 shows the power factor measurement block. The input power factor of power factor corrected electronic ballast can be improved close to the unity. From the figure we can see that the input current and voltage are taken for the power factor correction..

VI.SIMULATION RESULT

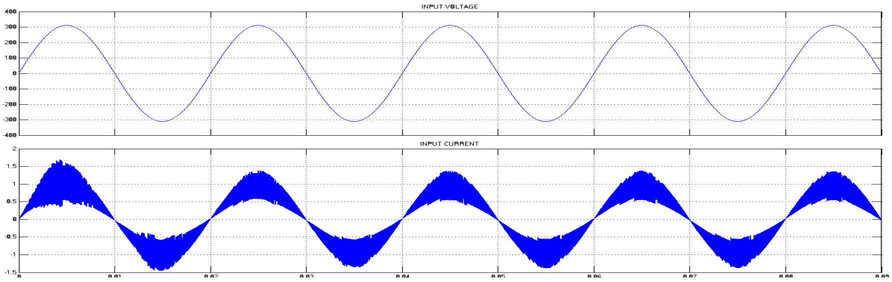

Fig.8: Input voltage and input current waveform

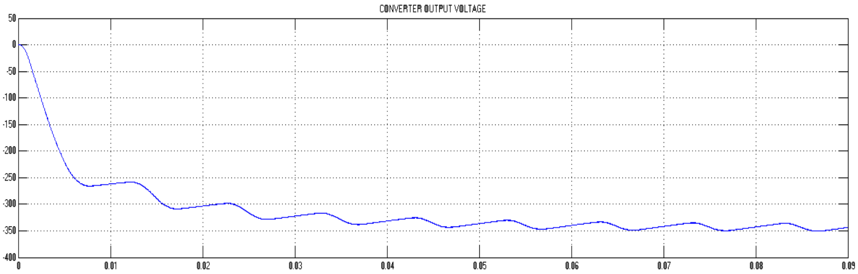

Fig.9: Converter output voltage waveform

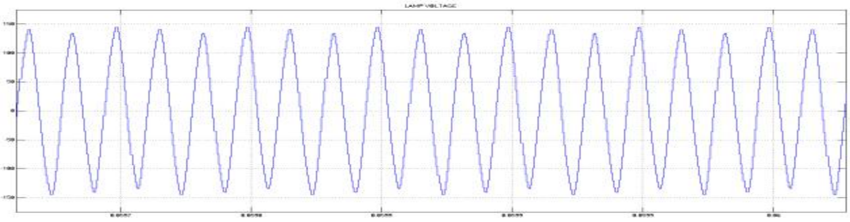

Fig.10: Voltage across Lamp

VII.CONCLUSION

A buck-boost converter has provided with low crest factor and almost unity power factor. In this buck-boost converter based electronic ballast the first section is buck-boost converter and the second is resonant inverter. The power factor and THD obtained from the simulation are 0.9647 and 2% respectively. The zero voltage switching has been confirmed with the series resonant inverter which is operating at lagging power factor. It reduces the switching losses at high frequency operation and also improves the overall efficiency.

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